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THE MORPHOLOGY OF NEMATODES[1/]

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An understanding of the morphology of nematodes is fundamental to their identification. Nematodes (Gr. thread-like) are distinguished from other organisms by their morphology. Their main body axis is longitudinal; that is, growth in length exceeds that in width. They are primarily bilaterally symmetrical and have two lateral sides, a dorsal (back) side, and a ventral (front) side which includes body openings (fig. 1-A, D). Unlike some "worms", nematodes are not segmented, are generally colorless, and they do not have a true body cavity lined with epithelial tissue.

Nematode structure includes a body wall, digestive, nervous, excretory, and reproductive system, but lacks a typical circulatory, respiratory, and endocrine system (fig. 1). The body wall is composed of somatic muscles, hypodermis, and cuticle. The cuticle is the outermost layer which provides support and protection; it is nonliving and often has elaborations which are important for identification. The cuticle of most nematode species has alternating horizontal grooves and ridges at regular intervals, termed "striations" if fine (fig. 1-A), or "annulations" if coarse; some nematodes also have longitudinal markings. Lateral lines and alae (ridges) extend the length of the two sides of most nematodes (fig. 1-A), and their number may be important for identification. Caudal alae (bursae) are flaps of cuticle which commonly occur in pairs on males and may assist in copulation (fig. 1-D). Additional cuticular elaborations include punctations, papillae, and elongate projections such as setae, spines, or bristles. The hypodermis underlies and is involved in producing the cuticle. Somatic muscles form the innermost layer of the body wall. These muscles are spindle-shaped and function in body movement and locomotion.

Morphology of the digestive system is variable and therefore, important in distinguishing among major groups of nematodes. The system includes three regions, which we will describe in relation to a typical plant parasite (fig. 1); 1) foregut (includes stoma, esophagus, and esophago-intestinal valve), 2) midgut (intestine), 3) hindgut (rectum, valve, and associated structures). The stoma of most plant parasites is specialized as a needle-like stylet which includes a cone, shaft, and knobs (fig. 1-B), and a fine lumen extends through the stylet, Muscles are attached to the knobs, and their contraction may force the pointed cone into a host for feeding. The esophagus is posterior to the stylet, and although it may be reduced or modified, it typically includes a procorpus, metacorpus, isthmus, basal bulb, and esophago-intestinal valve (fig. 1-A). An esophageal lumen is anteriorly continuous with that of the stylet and posteriorly continuous with the lumen of the intestine. Muscles are usually concentrated in the metacorpus which functions as a pump during feeding (fig. 1-A, B). The basal bulb may be modified into lobes, and generally consists of three glands: two subventral with each having a duct that terminates as an orifice in the lumen of the metacorpus, and one dorsal which typically secretes digestive enzymes through an orifice near the base of the stylet (fig. 1-A, B). The posterior terminus of the esophagus is the esophago-intestinal valve (fig. 1-A); this valve prevents regurgitation from the intestine. The midgut, or intestine, extends most of the length of a nematode and functions in absorption and storage of nutrients. The hindgut includes a rectum which terminates as a simple opening or anus in females, but in males a cloaca is formed by merging of the digestive and reproductive systems (fig. 1-A, B). The hindgut of males is best studied with the reproductive system.

The nerve ring, a concentration of nerves which encircle the isthmus, is the most visible part of the nervous system (fig. 1-A). Bundles of longitudinal nerves extend anteriorly and posteriorly from the ring and innervate the entire body. Nematodes have several sense organs including innervated cuticular elaborations such as papillae, setae, and bristles. Amphids, which occur as single pair in the head region (fig. 1-C), are generally the largest sense organ and may enable the nematode to respond to certain chemicals. Most plant parasites also have a pair of sensory phasmids which usually occur posteriorly, one on each lateral side (fig. 1-A).

Plant-parasitic nematodes usually have an excretory system which opens through the cuticle in the vicinity of the nerve ring (fig. 1-A). The system may include various tubes and glands, and it is thought to regulate salt concentration.

The nematode reproductive system is especially variable. Some species are hermaphroditic and others are parthenogenetic; however, most have distinct males and females and can reproduce by cross fertilization. The female reproductive tract is basically tuboid and may consist of one tube (monodelphic) or two similar tubes (didelphic) (fig. 1-A). The ovary occurs at the distal end of the tube, from which cells mature into eggs. An oviduct extends from the ovary and is typically constricted, although it may include an enlarged region specialized for storage of sperm. The oviduct opens into a muscular uterus, which merges with the vagina, and an opening in the cuticle, the vulva (fig. 1-A).

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The male reproductive system is also tuboid, and the distal source of cells which mature into sperm is the testis (fig. 1-D). Most plant-parasites have one testis (monorchic) although some nematodes have two testes (diorchic). A seminal vesicle, which is specialized for sperm storage, usually occurs proximal to the testis. This joins with the vas deferens which is a long tube that leads to the cloaca and reproductive opening. The vas deferens may be modified with various glands, and the cloaca may be associated with a pair of elongate copulatory structure (spicules) (fig. 1-D).

Nematodes occur in nearly every habitat, and their variable biology is reflected by diverse morphological adaptations. Yet, they possess many fundamental characteristics which unite them as a cohesive and distinct group.

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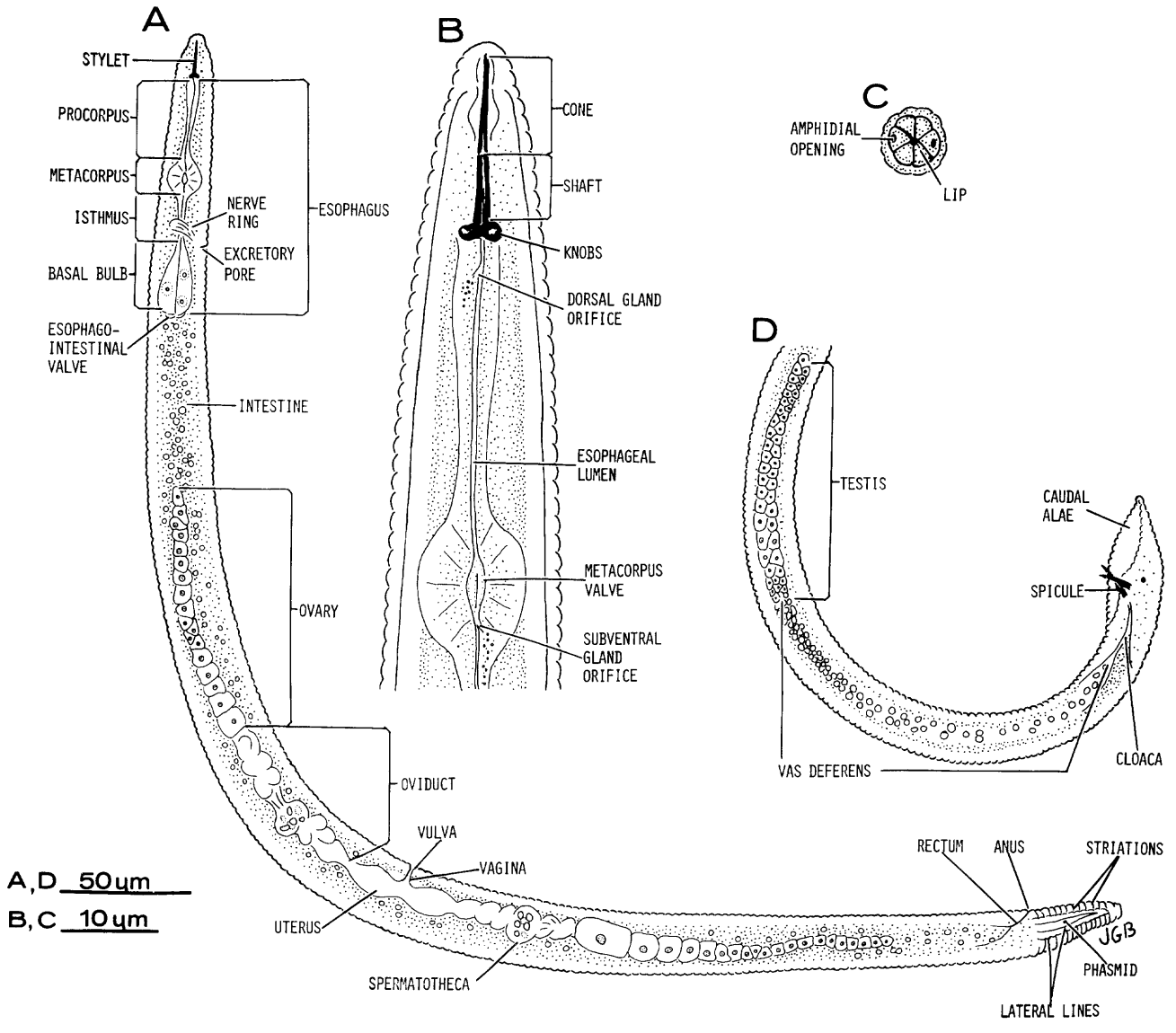

Fig. 1. Morphology of the stunt nematode (Tylenchorhynchus sp.). A. Females (lateral view). B. Anterior region of female (lateral view). C. Face view of female. D. Posterior region of male (lateral view).